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On the Measurement of the Inequality of Pivots of Transit Instruments by means of the Spherometer.

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In the autumn of 1875 it became necessary to determine the inequality of pivots of the eight Transit Instruments which had been used by the United States transit of *Venus* parties; and to have done this in the ordinary way, by means of the spirit level, would have occupied not less than three weeks. This was more time than I could conveniently spare for the purpose, and after some thought I contrived an instrument with which the required determinations were most accurately made, and the time expended was only an hour for each transit. This instrument was first tried on February 28, 1876, and as some copies of it have already been made for other astronomers, and it seems to be coming rapidly into use in the United States, perhaps a detailed description of it may be acceptable to the Royal Astronomical Society.

The spherometer-caliper, for such is the name of the instrument, is shown in the accompanying plate: fig. 1 being a front elevation; fig. 2 a side elevation; fig. 3 a plan; and fig. 4 a section through the point *f*, fig. 1. The lettering is the same on all the figures. The foundation plate, *b*, of the instrument carries two cylindrical guides, *d*, *d*, which are connected at their lower ends by the bar *e*. Into the foundation plate is screwed the brass piece *m*, to which is cemented the thick circular glass plate *c*. The two Ys, *a*, *a*, are also firmly screwed to the foundation plate. The brass plate *f* slides freely up and down between

the guides d, d; being kept in their plane by three loops, two of which pass around the right-hand guide, and one around the left-hand guide, as shown in the figure. The brass rod g, which passes through the piece m and the plate c without touching either of them, is firmly attached to the upper end of the plate f, and moves with it; while to the lower end of f is attached a second short brass rod which passes freely through the bar e and carries the nut h. There is an aperture in the plate f sufficiently large to permit the free passage of such transit pivots as the caliper is intended to measure.

In using the instrument the plate f is depressed by means of the nut h until p, one of the pivots whose inequality is to be measured, passes freely under the Ys, a, a. Then, the Ys having been properly adjusted upon the pivot, h is loosened, and the flat edge of the aperture in f is forced against the under side of the pivot by the spring i. Finally, the elevation of the end of the rod g above the glass plate c is accurately measured by means of a small spherometer. This process having been repeated upon the other pivot, the inequality of the two pivots will evidently be a function of the difference of the two readings of the spherometer. To insure the greatest possible accuracy of measurement, the glass plate c must be entirely free from strain, and the flat surface of the opening in f must be pressed with the same degree of force against the under surfaces of the two pivots. Both these conditions are evidently fulfilled in the construction of the instrument; and, as an additional precaution, the top of the rod g is capped with a carefully ground agate, upon which the point of the spherometer screw rests.

To find the relation between the difference of the two readings of the spherometer and the inequality of the pivots upon which they were made, put

$2i$ = the angle of the Ys of the caliper:
n = the difference between the readings of the spherometer on the two pivots:
R = the linear value of one revolution of the spherometer screw:
l = the distance between the pivots of the transit instrument:
p = the inequality of pivots; expressed in seconds of time, and to be considered positive when the eastern pivot is the largest.

Then, if the radius of the pivot undergoing measurement is r, the vertical distance from the angle of the Ys to the centre of the pivot will be $\frac{r}{\sin i}$; and the vertical distance from the centre of the pivot to the flat surface of the aperture in f will be r. Hence, if the vertical distance from the upper surface of the glass plate c to the angle of the Ys is C, the vertical distance from the upper surface of c to the flat surface of the aperture in f will be

$$C + r + \frac{r}{\sin i} = C + r\left(\frac{1+\sin i}{\sin i}\right). \qquad (1)$$

Similarly, for the other pivot, whose radius is r', the distance will be

$$C + r'\left(\frac{1+\sin i}{\sin i}\right). \qquad (2)$$

The difference between (1) and (2) is

$$(r-r')\left\{\frac{1+\sin i}{\sin i}\right\} \qquad (3)$$

which is the space moved through by the plate f when the second pivot was substituted for the first. As the plate f carried the rod g with it, this space must be equal to the linear value of the difference of the readings of the spherometer upon the two pivots. Hence

$$(r-r')\left\{\frac{1+\sin i}{\sin i}\right\} = n\mathrm{R}, \qquad (4)$$

and therefore

$$r-r' = \frac{n\mathrm{R}\sin i}{1+\sin i}, \qquad (5)$$

which is the inequality of pivots, expressed linearly. To convert it into seconds of time it must be divided by $l.15\tan 1''$, and thus we obtain finally

$$p = n\frac{\mathrm{R}\sin i}{l\,(1+\sin i)\,15\tan 1''}. \qquad (6)$$

By the kind permission of the Superintendent of the U.S. Naval Observatory, I am enabled to give some examples of the actual working of the spherometer-caliper. The first is the measurement, made March 20, 1876, of the inequality of pivots of the portable transit instrument, Stackpole & Bro., No. 1502.

Position of Pivot.	Clamp Pivot.	Lamp Pivot.	*n.*	*p.*
°	r	r	r	s
180	43·551	43·539		
	·550	·540		
	·549	·540		
	43·5500	43·5397	0·0103	0·031
225	43·549	43·536		
	·551	·540		
	·551	·540		
	43·5503	43·5387	0·0113	0·034

Position of Pivot.	Clamp Pivot.	Lamp Pivot.	*n*.	*p*.
o	r	r	r	s
270	43·551	43·540		
	·551	·539		
	·550	·540		
	43·5507	43·5397	0·0110	0·033
315	43·548	43·540		
	·552	·540		
	·553	·541		
	43·5510	43·5403	0·0107	0·032

Mean value of p = 0·032

Four diameters were measured in each pivot, their positions being indicated by the readings of the finding circle, which are contained in the first column of the table above. The readings of the spherometer upon the clamp pivot are contained in the second column, those upon the lamp pivot in the third column; and the resulting values of n and p are given in the fourth and fifth columns. The mode of measuring each diameter was as follows: The transit instrument being upon its reversing carriage, so that the pivots were entirely free, the axis was turned until that diameter of the pivot which it was desired to measure was vertical. Then the caliper was slipped on to the pivot and adjusted so that the surface of the plate c was perfectly level, after which the spherometer was placed upon it and very carefully read. This process was repeated three times; the caliper being removed from the pivot after each reading, so as to render the readings as independent of each other as possible. The value of n for any given diameter was, of course, the difference between the mean of the three readings upon the clamp pivot and the mean of the three corresponding readings upon the lamp pivot. To find p we require certain constants, the values of which in the present instance are

$$2i = 90°, \quad \mathrm{R} = 0{\cdot}02697 \text{ cm.}, \quad l = 50{\cdot}65 \text{ cm.}$$

Substituting these values in equation (6), we obtain

$$p = 3{\cdot}033n,$$

and accordingly, the values of p in the table above have been obtained from those of n by multiplying the latter quantities by 3·033. A comparison of the numbers in the second and third columns shows that the clamp pivot is the largest.

Our second example of the working of the spherometer-caliper is the measurement, made February 18, 1878, of the inequality of pivots of the portable transit instrument, Stackpole & Bro., No. 1506.

Position of Pivot.	Clamp Pivot.	Lamp Pivot.	n.	p.
°	r	r	r	s
180	43·237	43·218		
	·232	·219		
	·235	·217		
	43·2347	43·2180	0·0167	0·051
225	43·235	43·222		
	·238	·221		
	·238	·224		
	43·2370	43·2223	0·0147	0·045
270	43·237	43·215		
	·235	·219		
	·238	·218		
	43·2367	43·2173	0·0194	0·059
315	43·236	43·216		
	·239	·216		
	·238	·211		
	43·2377	43·2143	0·0234	0·071
			Mean value of p =	0·056

Upon reducing these measurements, my first impression was that the large value of p at 315° must have been erroneous, and I remeasured the pivot inequality at that point, with the result, $p = 0^{s}{\cdot}075$. This confirmed the first measurement, and showed beyond all possibility of doubt that one, or perhaps both of the pivots were elliptical. An examination of the spherometer readings upon the clamp pivot proves that it is round, at least within the limits of error of observation; but with the lamp pivot the case is different. The largest spherometer reading upon it is at 225°, and the smallest at 315°. These are therefore the approximate positions of the major and minor axes of the ellipse. The difference of the spherometer readings at these points is $0^{r}{\cdot}0080$. Substituting this in equation (5), we find

that the semi-major axis exceeds the semi-minor one by 0·000089 cm.—a small quantity truly, but one about which there can be no mistake. This degree of ellipticity is so slight that it may be neglected in a portable instrument, and accordingly we adopt the mean value of p, which is $0^{s}{\cdot}056$; the clamp pivot being the largest.

More examples might be given, but the above suffice to show that, for measuring pivot inequalities, the spherometer-caliper possesses the following advantages over the spirit level:—1st, It is more accurate; 2nd, it shows the exact form of each pivot; 3rd, it is at least ten times more expeditious.

To secure the advantage of accuracy to its fullest extent the following points must be attended to:—1st, The spherometer must be as light as possible: the one shown in the plate weighs only 37·10 grammes; 2nd, the screw of the spherometer must be entirely free from dead motion; 3rd, the surface of the glass plate c must always be truly levelled before applying the spherometer to it. In a properly constructed instrument there should be no difficulty about the second of the above conditions, but unfortunately few spherometers are properly constructed. The makers generally provide some means of tightening the main nut, thinking in that way to destroy the dead motion; but if any serious attempt is made to use this arrangement, it will be found that long before the dead motion disappears, the motion of the screw becomes so stiff as to render the instrument totally unmanageable. In my own instrument, immediately below the main nut there is a supplementary one with three elastic arms, which are attached to the frame of the instrument in such a manner that any required strain can be put upon them. The spherometer screw passes through both these nuts, and by carefully adjusting the tension on the arms of the supplementary one, which is two or three threads below the other, the two can be so pressed toward each other as to eliminate all dead motion, and yet leave the movement of the screw as light as may be desired. The importance of the third condition mentioned above depends upon the fact that all well-made spherometers are so balanced that when they stand upon a level surface their centre of gravity is in the screw. Consequently, when the screw comes in contact with the object to be measured, the three feet of the instrument will lift simultaneously if it is standing upon a level surface, but if it is standing upon a surface ever so little inclined, there will be a tendency for one foot to lift before the others, and the accuracy of measurement will be greatly impaired.

The spherometer-caliper shown in the drawing which accompanies this paper is the first one ever constructed, and as it is not furnished with any means of varying the size of the aperture in the plate f, it is only applicable to pivots whose diameter is not far from 3·40 cm. In a much larger instrument, recently made for Professor C. A. Young, of Princeton College, the flat edge of the aperture in the plate f consists of a bar which can be

adjusted to any desired height upon the plate, and thus the instrument is rendered capable of measuring pivots of almost any size.

Washington, 1878, *May* 22.

Spectroscopic Results for the Motions of Stars in the Line of Sight, made at the Royal Observatory, Greenwich. III.

(*Communicated by the Astronomer Royal.*)

The Results for Star Motions here given are in continuation of those printed in the *Monthly Notices* for 1876, May and November, and the general arrangement is the same.

Up to 1877, May 2, the observations were made with the ten-prism spectroscope (two or four prisms only being used for star work), and the method of observation has been sufficiently described in preceding communications. On 1877, August 23, the half-prism spectroscope was brought into use, but the observations suffered interruption during the oppositions of *Mars* and *Saturn*, and it was not till 1877, November 14, that this work was again brought into regular train. The principle of the new spectroscope is fully described in a paper in the *Proceedings of the Royal Society*, No. 179, 1877; and it may be sufficient to state here that the full train consists of two compound half-prisms, each being the half of a direct-vision prism, cut in two by a plane perpendicular to the base. Either one or two of the half-prisms can be used at pleasure: with one half-prism a dispersion of 20° from A to H, equivalent to four prisms of 60°, is obtained; and with two half-prisms a dispersion of 75° from A to H, equivalent to fifteen prisms of 60°. The number of half-prisms used is denoted by the Roman numerals I and II. The full dispersion of 75°, which is far greater than any hitherto used for stellar observations, has been applied recently to some of the brighter stars, including one of the second magnitude, and no difficulty has been experienced in making satisfactory comparisons with this high power. As a check against possible instrumental error arising from maladjustment of the spectroscope, comparisons have been regularly made, either before or after the observations, with the spectrum of the Moon or with that of the sky, the results of which are given at the end of the table.

Motions of Stars in the Line of Sight in Miles per Second.

(+ denotes Recession; − Approach.)

One division in the width of the slit of the Ten-prism Spectroscope corresponds to 0·0013 inch; one revolution of the slit screw of the Half-prism Spectroscope corresponds to 0·01 inch; the weights are on a scale 1–5 for *each* observation; the Means have been taken for the whole series of observations, including former results.

The initials W.C. and M. are those of Mr. Christie and Mr. Maunder respectively.

Date.	Observer.	No. of Measures.	Weight.	No. of Prisms.	Position-Circle.	Width of Slit.	Line.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
					°	d d					
α Andromedæ.											
1876 Nov. 17	M.	2	2	2 & 4	6	2·9 & 3·1	F	+11·6	...	−69·1	Direct comparison.
Dec. 6	M.	2	3	4	6	2·8 & 4·0	F	+15·1	−39·1	−37·5	Indirect comparison; star line very difficult to bisect.
				Mean, Ten-prism Spectroscope					−34·4	−55·2	Weight 16.
α Arietis.											
1878 Feb. 6	M.	3	6	I	5	...	b_1	+18·2	+63·1	+45·5	Indirect comparison; spectrum rather tremulous.
Aldebaran.											
1877 Dec. 31	W.C.	2	4	I	95	...	b_1	+10·1	+22·5	+ 1·8	Indirect comparison.
31	M.	2	4	I	95	...	b_1	+10·1	+21·2	+18·5	Indirect comparison.

1878 Jan. 10	M.	2	4	I	95	...	b_1	+12·8	+20·8	+20·1	Indirect comparison; spectrum very tremulous; definition poor.
23	M.	2	2	I	95	...	b_1	+15·6	+38·2	+41·3	Indirect comparison; definition very bad.
29	M.	2	2	I	95	...	b_1	+16·6	+15·9	+ 4·8	Indirect comparison; spectrum very tremulous; observation very difficult.
Apr. 8	M.	2	6	II	5	r 0·072	b_1	+13·8	+15·2	+18·0	Indirect comp.; definition only moderate.
				Mean	Ten-prism Spectroscope				+35·1	+48·7	Weight ½.
					Half-prism Spectroscope				+20·8	+16·4	Weight 22.
							Capella.				
1876 Nov. 1	M.	1	2	2	6	d 3·8	F	−11·1	...	+67·0	Direct comparison.
17	M.	2	3	4	6	3·8 & 1·4	F	− 7·0	...	+31·4	Direct comparison.
17	M.	1	1	6	6	2·1	b_1	− 7·0	...	+61·2	Direct comparison.
1878 Mar. 15	M.	2	8	I	5	r 0·085	b_1	+17·0	+39·9	+42·0	Indirect comparison.
16	W.C.	3	2½	I	120	0·080	F	+17·0	...	+34·0	Direct comparison.
16	W.C.	3	7	I	120	0·073	b_1	+17·0	...	− 2·6	Indirect comp.; the bright line of the micrometer being ragged, the comparison was uncertain.
25	M.	2	10	I	95	0·151	F	+16·4	+15·9	+20·9	Indirect comp.; definition very good.
Apr. 1	M.	2	6	I	5	0·128	b_1	+15·7	+55·8	+57·0	Indirect comp.; spectrum very tremulous.
				Mean	Ten-prism Spectroscope				+16·0	+30·9	Weight 18.
					Half-prism Spectroscope				+33·9	+27·3	Weight 29.

Date.	Observer.	No. of Measures.	Weight.	No. of Prisms.	Position-Circle.	Width of Slit.	Line.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
					°	d					
β Orionis.											
1877 Mar. 10	M.	2	3	4	2½	2·5	F	+15·8	+ 7·2	+ 9·4	Indirect comparison.
Dec. 31	M.	3	6	I	95	...	F	+ 7·0	+20·0	+14·5	Indirect comparison; definition fair.
1878 Jan. 10	M.	3	7	I	95	...	F	+ 9·5	+26·0	+21·6	Indirect comparison; definition poor.
23	W.C.	3	9	I	95	...	F	+12·2	...	+17·9	Indirect comparison for first two obs.; direct for last.
29	M.	3	3	I	95	...	F	+13·2	+14·1	+13·0	Indirect comparison; spectrum very tremulous; definition very poor.
Feb. 6	M.	2	2	I	5	...	F	+14·4	+34·9	+38·4	Indirect comp.; spectrum very tremulous.
				Mean	Ten-prism Spectroscope				+18·5	+20·2	Weight 8.
					Half-prism Spectroscope				+23·0	+19·1	Weight 22½.
β Tauri.											
1878 Jan. 29	M.	3	3	I	95	...	F	+14·2	− 9·8	−10·2	Indirect comparison; spectrum steady; definition fair.
γ Orionis.											
1878 Jan. 29	M.	5	10	I	95	...	F	+14·0	− 0·5	− 2·4	Indirect comparison.
29	M.	1	2	I	95	...	F	+14·0	...	−14·0	Indirect comparison.
Feb. 17	W.C.	2	4	I	0	...	F	+16·9	+ 2·8	+11·0	Indirect comparison.
				Mean:	Half-prism Spectroscope				+ 0·4	− 0·5	Weight 15.

δ Orionis.

1877 Dec. 31	M.	1 est.	1	I	95	...	F	+ 5·9	...	−18·0	Direct comparison.
1878 Jan. 10	M.	2	1	I	95	...	F	+ 8·7	+21·1	+17·5	Indirect comparison; star faint; definition bad.
23	W.C.	2	3	I	95	...	F	+11·9	...	+ 0·0	Indirect comparison.
Feb. 18	M.	2	2	I	6	...	F	+16·1	+34·6	+45·3	Indirect comparison.
					Mean	Ten-prism Spectroscope			+25·4	+21·9	Weight 7.
						Half-prism Spectroscope			+30·1	+12·8	Weight 5.

ε Orionis.

1877 Mar. 10	M.	2	0	4	2½	...	F	+16·9	(−46·1)	...	Star line scarcely visible; observations discordant.
10	M.	2	6	2	2½	4·6 d	F	+16·9	−48·7	−61·4	Indirect comparison.
Dec. 31	M.	2	3	I	95	...	F	+ 5·5	+29·9	+18·7	Indirect comparison; star line very faint.
1878 Jan. 23	W.C.	1	2	I	95	...	F	+11·6	...	+24·5	Indirect comparison.
Feb. 18	M.	3	3	I	6	...	F	+15·9	+20·9	+23·3	Indirect comparison.
					Mean	Ten-prism Spectroscope			−48·7	−61·4	Weight 6.
						Half-prism Spectroscope			+25·4	+21·9	Weight 7.

ζ Orionis.

1878 Feb. 18	M.	2	2	I	6	...	F	+15·7	+17·4	+29·8	Indirect comparison.

α Orionis.

Date.	Observer.	No. of Measures.	Weight.	No. of Prisms.	Position-Circle.	Width of Slit.	Line.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
					°	d d					
1877 Feb. 28	M.	3	3	2	6	1·4 & 2·0	b_4	+17·2	+19·2	+17·1	Indirect comparison; definition poor; Moon bright.
						d					
Mar. 10	M.	2	8	4	$2\frac{1}{2}$	2·6	b_4	+17·8	+22·1	+11·0	Indirect comparison; star line seen well.
Dec. 31	M.	2	4	I	95	...	b_4	+ 4·2	+16·9	+14·9	Indirect comparison; spectrum tremulous; definition variable.
1878 Feb. 18	M.	3	12	I	6	...	b_1	+16·1	+33·9	+36·4	Indirect comparison; definition good.
						r					
Mar. 15	M.	2	3	I	5	0·098	b_4	+17·9	+16·8	+15·8	Indirect comp.; spectrum tremulous.
Apr. 1	M.	3	12	I	5	0·128	b_1	+17·1	+20·5	+19·3	Indirect comparison; spectrum tremulous, but definition fair.
8	M.	3	8	II	5	0·072	b_1	+16·3	+ 9·0	+ 9·5	Indirect comp.; spectrum tremulous.
					Mean	Ten-prism Spectroscope			+21·3	+12·7	Weight 11.
						Half-prism Spectroscope			+21·6	+21·8	Weight 39.

β Aurigæ.

						r					
1878 Apr. 11	M.	4	2	I	5	0·072	F	+15·6	+11·5	+22·3	Indirect comp.; star line very difficult.

Sirius.

1877	Feb. 28	M.	2	5	4	6	$5^{d}\cdot1$ & $2^{d}\cdot7$	F	+12·2	+ 9·3	+14·5	Direct comparison; definition poor; Moon bright.
1878	Feb. 17	W.C.	4	5	I	0	...	F	+10·5	+22·1	+ 8·3	First two comps. direct; last two indirect.
	18	M.	2	6	I	6	...	F	+10·7	+30·4	+32·8	Indirect comparison.
	Mar. 25	M.	2	4	I	95	$0^{r}\cdot151$	F	+14·1	+23·2	+41·8	Indirect comparison; spectrum very tremulous.
							Mean { Ten-prism Spectroscope			+19·9	+24·8	Weight 29.
							Mean { Half-prism Spectroscope			+25·7	+27·0	Weight 15.

Castor.

1877	Mar. 10	M.	1	2	4	$2\frac{1}{2}$	$3^{d}\cdot4$	F	+16·2	− 3·9	+ 5·7	Indirect comparison.
1878	Feb. 25	M.	2	2	I	95	...	F	+13·9	+26·9	+38·4	Indirect comparison; star line ill defined.
	Mar. 25	M.	2	7	I	95	$0^{r}\cdot141$	F	+17·6	+33·7	+30·5	Indirect comparison.
	30	M.	2	2	I	5	0·073	F	+17·9	+54·4	+43·7	Indirect comparison; definition poor; and observation difficult.
							Mean { Ten-prism Spectroscope			+25·3	+22·3	Weight 19.
							Mean { Half-prism Spectroscope			+36 2	+34·3	Weight 11.

Procyon.

Date.	Observer.	No. of Measures.	Weight.	No. of Prisms.	Position-Circle.	Width of Slit.	Line.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
					°	d					
1877 Mar. 5	M.	2	5	2	10	2·0	F	+14·0	+30·7	+19·6	Indirect comparison; spectrum bright and steady.
1878 Feb. 25	M.	2	6	I	95	...	F	+12·3	+15·6	+20·0	Indirect comp.; spectrum tremulous.
						r					
Mar. 16	W.C.	2	0	I	120	0·073	b_1	+15·7	(−59·8)	(−25·2)	Indirect comp.; star lines very faint; observations discordant *inter se*.
25	M.	2	8	I	95	0·141	F	+16·7	+ 7·5	+10·3	Indirect comparison; definition good.
30	M.	2	5	I	5	0·123	F	+17·2	+39·6	+46·2	Indirect comp.; definition poor.
Apr. 20	M.	2	4	II	5	0·100	F	+17·4	+16·4	+34·2	Indirect comparison; much interrupted by light cloud.
					Mean	Ten-prism Spectroscope			+42·8	+35·3	Weight 24.
						Half-prism Spectroscope			+22·0	+22·6	Weight 23.

Pollux.

						d d					
1877 Feb. 28	M.	2	2	2	6	1·0 & 1·8	b_1	+13·8	−52·1	−89·8	Indirect comparison; definition poor; Moon bright.
						d					
Mar. 10	M.	2	6	4	$2\frac{1}{2}$	2·6	b_1	+15·7	−30·2	−45·7	Indirect comparison.
1878 Feb. 18	M.	4	12	I	6	...	b_1	+11·5	+ 6·2	+ 7·7	Indirect comparison; definition variable; observations discordant *inter se*.
25	M.	1	1	I	95	...	b_1	+13·1	+15·7	+15·3	Indirect comparison; spectrum tremulous; definition bad.
						r					
Mar. 13	W.C.	2	3	I	90	0·120	b_1	+16·1	−56·2	−34·9	Indirect comparison.

	15	M.	3	5	I	5	0·085	b_1	+16·4	+ 9·2	+10·4	Indirect comparison; definition variable.
	16	W.C.	2	6	I	120	0·073	b_1	+16·5	−20·4	−25·2	Indirect comparison.
	25	M.	4	8	I	95	0·141	F	+17·5	−52·3	−49·8	Indirect comp.; definition deteriorating.
	30	M.	2	3	I	5	0·123	F	+17·9	−33·3	−34·2	Indirect comparison; definition poor.
Apr.	1	M.	4	13	I	5	0·128	b_1	+18·0	−28·0	−31·1	Indirect comparison.
	7	W.C.	3	6	II	90	0·070	b_1	+18·1	−35·6	−26·3	Indirect comparison; star line seen pretty distinctly.
	8	M.	3	3	II	5	0·072	b_1	+18·1	−23·0	−25·9	Indirect comp.; spectrum very tremulous.
						Mean	Ten-prism Spectroscope			−35·7	−56·7	Weight 8.
							Half-prism Spectroscope			−22·0	−20·5	Weight 60.
									α Hydræ.			
1878 Mar.	13	W.C.	3	4½	I	90	r 0·120	b_1	+ 8·0	+57·6	+24·2	Indirect comparison.
									ε Leonis.			
1878 Apr.	1	M.	2	3	I	5	0·128	b_1	+14·5	−30·4	−36·3	Indirect comparison; star line distinct, but spectrum faint and tremulous.
									Regulus.			
1877 Mar.	5	M.	1	3	2	10	d 1·7	F	+ 5·6	+25·7	+23·7	Indirect comparison.
1878 Mar.	30	M.	2	6	I	5	r 0·073	F	+12·3	+18·5	+18·6	Indirect comparison.
Apr.	11	M.	3	10	I	5	0·027	F	+14·8	+26·6	+21·6	Indirect comparison; definition fair.
						Mean	Ten-prism Spectroscope			+30·7	+32·1	Weight 25.
							Half-prism Spectroscope			+23·6	+20·5	Weight 16.

Date.	Observer.	No. of Measures.	Weight.	No. of Prisms.	Position-Circle.	Width of Slit.	Line.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
						γ Leonis.					
					°	r					
1878 Mar. 13	W.C.	3	4	I	90	0·120	b_1	+ 7·9	−13·5	− 3·4	Observations discordant *inter se.*
Apr. 1	M.	2	7	I	5	0·096	b_1	+12·7	−42·5	−40·4	Indirect comparison.
8	M.	3	3	II	5	0·072	b_1	+14·1	−20·8	−23·2	Indirect comparison.
					Mean	Ten-prism Spectroscope			−54·7	−54·0	Weight 8.
						Half-prism Spectroscope			−29·6	−26·1	Weight 14.
						β Ursæ Majoris.					
						d d					
1877 Apr. 14	M.	2	6	2	5	3·9 & 3·6	F	+11·9	+22·2	+30·8	Indirect comp.; spectrum fairly defined.
May 2	M.	2	6	2	3	d 3·0	F	+12·7	+41·1	+48·9	Indirect comparison; star spectrum and line well seen.
						Ten-prism Spectroscope			+28·3	+32·2	Weight 21.
						β Leonis.					
						r					
1878 Mar. 25	M.	2	4	I	95	0·141	F	+ 4·8	+44·3	+53·4	Indirect comparison; definition poor.
30	M.	3	8	I	5	0·073	F	+ 6·2	+57·0	+54·6	Indirect comparison.
					Mean	Ten-prism Spectroscope			−32·7	−31·0	Weight 2.
						Half-prism Spectroscope			+52·8	+54·2	Weight 12.
						γ Ursæ Majoris.					
						d					
1877 May 2	M.	2	6	2	3	3·2	F	+11·8	+24·9	+20·4	Indirect comparison; star spectrum and line well seen.

							δ Ursæ Majoris.				
1877 May 2	M.	8	4	2	3	3·3	F	+10·8	+ 3·9	+ 0·1	Indirect comp.; spectrum very faint.
							γ Virginis.				
1878 Apr. 11	M.	2	3	1	5	^{r}0·072	F	+ 4·3	+31·8	+26·0	Indirect comparison; definition fair.
							ϵ Ursæ Majoris.				
1877 May 2	M.	2	6	2	3	^{d}3·3	F	+ 9·6	+ 5·9	+12·3	Indirect comparison.
							α Virginis.				
1878 Mar. 30	M.	4	10	1	5	^{r}0·073	F	− 3·8	− 0·5	− 2·3	Indirect comparison; definition fair.
Apr. 11	M.	2	2	1	5	0·072	F	0·0	+26·8	+25·3	Indirect comparison; definition bad.
May 11	M.	2	4	1	5	...	F	+ 8·7	− 9·3	− 8·7	Indirect comp.; spectrum exceedingly tremulous.
					Mean	Ten-prism Spectroscope			+37·9	+50·9	Weight 4.
						Half-prism Spectroscope			+ 0·7	− 0·5	Weight 16.
							ζ Ursæ Majoris.				
1877 May 2	M.	2	6	2	3	^{d}3·0	F	+ 8·6	+ 5·5	+16·1	Indirect comparison; star spectrum well defined.
							η Boötis.				
1878 Apr. 1	M.	2	4	1	5	^{r}0·128	b_1	− 1·5	−33·4	−34·9	Indirect comparison.

Arcturus.

Date.	Observer.	No. of Measures.	Weight.	No. of Prisms.	Position-Circle.	Width of Slit.	Line.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
					°	d					
1877 Mar. 5	M.	2	7	4	5½	2·5	b_1	− 9·6	−16·2	−50·9	Indirect comparison; lines fairly well defined.
						r					
1878 Mar. 30	M.	4	16	I	5	0·073	F	− 3·3	−17·2	−16·9	Indirect comparison; spectrum steady; definition fair.
Apr. 7	W.C.	2	2	II	90	0·070	b_1	− 1·2	−10·3	− 7·8	Indirect comparison.
8	M.	3	12	II	5	0·072	b_1	− 0·9	−18·3	−20·7	Indirect comp.; definition very good.
					Mean { Ten-prism Spectroscope				−36·2	−45·1	Weight 73.
					Mean { Half-prism Spectroscope				−17·2	−17·8	Weight 30.

ϵ_2 Boötis.

Date.	Observer.	No. of Measures.	Weight.	No. of Prisms.	Position-Circle.	Width of Slit.	Line.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
						r					
1878 Apr. 1	M.	3	9	I	5	0·096	b_1	− 3·4	−26·3	−24·3	Indirect comparison; definition fair.
					Mean { Ten-prism Spectroscope				+ 4·1	− 2·3	Weight 21.
					Mean { Half-prism Spectroscope				−26·3	−24·3	Weight 9.

α Coronæ.

Date.	Observer.	No. of Measures.	Weight.	No. of Prisms.	Position-Circle.	Width of Slit.	Line.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
1877 Aug. 31	M.	3	8	I	...	...	F	+11·4	+54·4	+67·9	Indirect comparison.
						r					
1878 Mar. 25	M.	3	6	I	95	0·141	F	− 7·6	+54·3	+54·4	Indirect comparison; definition only occasionally good.
					Mean { Ten-prism Spectroscope				+36·0	+39·7	Weight 13.
					Mean { Half-prism Spectroscope				+55·4	+62·1	Weight 6.

						α Ophiuchi.					
1877 Aug. 31	M.	2	8	I	...	...	F	+14·3	+61·3	+89·6	Direct comparison.
1878 Apr. 11	M.	3	3	I	5	$\overset{r}{0}$·072	F	−12·7	− 9·0	− 7·5	Indirect comparison; star line very difficult to bisect.
						α Lyræ.					
1876 Dec. 6	M.	2	5	6	6	$\overset{d}{4}$·7 & $\overset{d}{2}$·6	F	+ 4·3	−49·8	−43·8	Indirect comparison.
						Ten-prism Spectroscope			−39·1	−34·6	Weight 92.
						ζ Aquilæ.					
1876 Nov. 17	M.	2	3	2	6	3·0 & 3·9	F	+11·9	...	−66·9	Direct comp.; definition fairly good.
1877 Aug. 23	M.	3	9	I	...	...	F	+ 9·9	−60·3	−70·3	Indirect comparison.
						γ Aquilæ.					
1877 Nov. 14	M.	2	5	I	95	...	b_1	+14·8	− 3·7	− 2·6	Indirect comparison.
						γ Cygni.					
1877 Nov. 14	M.	2	$2\frac{1}{2}$	I	95	...	b_1	+10·2	−27·9	−40·5	Indirect comparison; definition bad.
						Ten-prism Spectroscope			−19·7	−20·4	Weight $24\frac{1}{2}$.
						α Cygni.					
1877 Nov. 14	M.	2	7	I	95	...	b_2, b_1	+ 9·3	−69·5	−61·3	Indirect comp.; definition improving.
						Ten-prism Spectroscope			−40·2	−41·3	Weight 40.

ϵ *Cygni.*

Date.	Observer.	No. of Measures.	Weight.	No. of Prisms.	Position-Circle.	Width of Slit.	Line.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
					°	d					
1877 Nov. 14	M.	2.	4	I	95	...	b_1	+ 12·2	+ 24·2	± 25·7	Indirect comparison; definition poor.
				Ten-prism Spectroscope					± 11·8	+ 14·9	Weight $3\frac{1}{2}$.

Moon.

1878 Jan. 17	M.	4	...	I	5	...	b_1	...	= 0·7	...	Lines in the spectrum of the Moon rather faint.
						r					
Feb. 17	W.C.	1	...	I	0	0·156	F	...	− 6·3	0·0	
Mar. 13	W.C.	4	...	I	90	...	b_1	...	− 1·9		
16	W.C.	4	...	I	120	...	b_1	...	− 6·4		
Apr. 8	M.	6	...	II	5	0·072	b_1, b_2, b_4	...	0·0		
11	M.	4	...	I	5	...	F	...	0·0		
May 8	M.	4	...	II	5	...	F	...	+ 0·3	...	The coincidence of the two spectra very perfect.
11	M.	4	...	I	5	...	F	...	+ 0·1		

Sky Spectrum.

1878 Apr. 2	M.	15	...	I	5	...	b_1	...	+ 1·8		
8	W.C.	3	...	II	90	...	b_1, b_2, b_4	...	+ 3·0		
8	M.	6	...	II	90	...	b_1, b_2, b_4	...	+ 1·7		
9	M.	8	...	II	5	...	b_1, b_2, b_4	...	+ 0·8		

As the results with the half-prism spectroscope are quite independent of those formerly obtained, it may be interesting to compare the two sets obtained at Greenwich with those of Dr. Huggins. The following table gives the comparison of the motions found for 51 stars, all of which have been spectroscopically examined at Greenwich. Where no number is set down the result is to be considered as still somewhat uncertain.

The agreement appears to be as satisfactory as can be expected in such delicate observations.

Motions of Stars in the Line of Sight.

\+ denotes recession ; − approach.

The weights are on a scale 1 to 5 for *each* observation.

Star's Name.	Dr. Huggins' Results.	Ten-prism Spectroscope.		Half-prism Spectroscope.	
		Results.	Weight.	Results.	Weight.
α Andromedæ	−	−45	16		
α Arietis				+	6
Aldebaran	+	+	½	+19	22
Capella	+	+24	18	+30	29
β Orionis	+15	+19	8	+21	22½
β Tauri				−	3
γ Orionis				0	15
δ Orionis				+18	5
ε Orionis		−	6	+23	7
ζ Orionis				+	2
α Orionis	+22	+17	11	+22	39
β Aurigæ				+	2
Sirius	+18 to 22	+22	29	+26	15
Castor	+23 to 28	+24	19	+35	11
Procyon	+	+33	24	+22	23
Pollux	−49	−46	8	−21	60
α Hydræ				+	4½
ε Leonis				−	3
Regulus	+12 to 17	+31	25	+22	16
γ Leonis	−	−54	8	−28	14
β Ursæ Majoris	+17 to 21	+30	21		
α Ursæ Majoris	−46 to 60	−	4		
β Leonis	+	−	2	+53	12
γ Ursæ Majoris	+17 to 21	+	6		
δ Ursæ Majoris	+17 to 21	+	4		
γ Virginis				+	3

Star's Name.	Dr. Huggins' Results.	Ten-prism Spectroscope.		Half-prism Spectroscope.	
		Results.	Weight.	Results.	Weight.
ϵ Ursæ Majoris	+17 to 21	+	6		
α Virginis	+	+	4	0	16
ζ Ursæ Majoris	+ 17 to 21	+	6		
η Ursæ Majoris	+	−32	7		
η Boötis				−	4
Arcturus	−55	−41	73	−18	30
ϵ_2 Boötis		+ 1	21	−	9
α Coronæ	+	+38	13	+58	14
β Herculis		−	3		
α Herculis		−31	$5\frac{1}{2}$		
β Draconis		+ 7	$1\frac{1}{2}$		
α Ophiuchi		?		?	
γ Draconis		−18	$14\frac{1}{2}$		
α Lyræ	−44 to 54	−37	92		
ζ Aquilæ		?		−	9
γ Aquilæ		−	1	−	5
δ Cygni		−23	12		
α Aquilæ		?			
γ Cygni	−	−20	$24\frac{1}{2}$	−	$2\frac{1}{2}$
α Cygni	−39	−41	40	−	7
ϵ Cygni		+13	$3\frac{1}{2}$	+	4
ϵ Pegasi		−24	$11\frac{1}{2}$		
Fomalhaut		?			
β Pegasi		+20	10		
α Pegasi	−	−22	16		

Royal Observatory, Greenwich,
1878, *June* 14.

On the Photographs of the Transit of Venus.

By Captain G. L. Tupman, R.M.A.

(*Communicated by the Astronomer Royal*).

The photographs that have been measured were taken with the five Photoheliographs made by Mr. Dallmeyer for the Transit of *Venus* Expeditions on "Patent Plates," 6 inches square, the images of the Sun being very nearly 3·9 inches in diameter. The Dry process of Captain Abney, R.E., described in the *Monthly Notices*, vol. xxxiv., p. 275, was used throughout.

The measuring instrument, designed by the Astronomer Royal for the purpose, the determination of the errors of graduation of its glass millimeter scale, and the method of obtaining the optical distortion of the Photoheliographs are sufficiently described in vol. xxxvi., p. 178. It was found by an elaborate investigation that the lines of equal distortion were sensibly circles concentric with the centre of the field. The actual correction for distortion for that zone of the field in which the points to be measured generally fall is shown in the following table. By the scale adopted, the distortion is taken as zero at the centre of the field and at the distance of about 47 millimeters from the centre. One millimeter corresponds to about 19·5 seconds of arc.

Distance from centre of field in millimeters	Luxor instrument.	Honolulu instrument.	Rodriguez instrument.	Burnham instrument.	Kerguelen instrument
	mm.	mm.	mm.	mm.	mm.
40	+·040	+·034	+·045	+·040	+·042
42	+·030	+·025	+·033	+·030	+·032
44	+·019	+·015	+·021	+·020	+·021
46	+·006	+·005	+·008	+·007	+·009
48	−·006	−·007	−·006	−·006	−·003
50	−·021	−·019	−·020	−·020	−·017
52	−·037	−·032	−·036	−·036	−·031

Before commencing the measures of a negative, the position of the line of centres was marked upon the film by a simple mechanical process. This operation was performed independently by Mr. Burton and myself with no sensible difference. In placing the negative in the instrument, the circular carrier was turned about until the line of centres was truly parallel to the direction of the sliding motion of the microscopes.

When the negatives are placed under the microscope with an amplification of only 5 or 6 diameters, the limbs of both planet and Sun, even those which are pretty sharp to the unaided eye, become extremely indistinct, and the act of bisecting the limb with the wire or cross of the micrometer is mere guesswork. The deposit of silver fades off gradually to nothing, and the denser the film the broader is the zone of fading off, and the more uncertain the measures. In many cases the difficulty is aggravated by ruggedness due to atmospheric disturbances, but the smooth and gradual fading off is the chief cause of uncertainty.

There is only *one* really sharp image in the whole collection, including the Indian and Australian contingents, and that is one of Captain Waterhouse's wet plates taken at Roorkee with a Dallmeyer instrument precisely similar to the others.

It should be remarked that in these instruments the artist has attempted to unite the photographic and visual foci on the collodion film. No doubt some sharpness of the photographic

image was thus sacrificed, but this has little or nothing to do with the unfortunate failure in the application of photography. Each photograph was measured six times by Mr. Burton and six times by me. I was not able to include in my series of measures all the photographs measured by Mr. Burton, for the reason that, when some of them were viewed through the microscope, there was nothing visible to bisect, either from the extreme faintness of the film or from its too gradual fading off. Mr. Burton generally employed a cross of webs, but I preferred a single very fine web, the breadth of which was eliminated in the mean by the mode of bisecting.

It has been suggested that the instrument should possess the power of rotating the Sun's image about a mechanical centre. This would be useful in some cases of ruggedness, but, in my opinion, would make no material difference in the accuracy of measurement. The rotation could only be applied to the limbs of the Sun,* whereas perhaps the greatest difficulty is with the limbs of the planet.

From the measures, corrected for distortion, are obtained the photographic diameters of the Sun and of *Venus*; the former presumably enlarged, the latter diminished by irradiation, in a sensibly equal degree. The sum of the measured diameters in millimeters is compared with the sum of the tabular diameters, subject to errors, for the scale value, and thus every photograph furnishes its own scale. The measured distance of centres *in arc*

$$\mathrm{M} = \frac{\text{distance of centres in millimeters} \times \text{sum of tabular diameters}}{\text{sum of measured diameters in millimeters}}.$$

This relation will be true, except when the Sun is near the horizon. As long as the refraction for the centre is sensibly the mean between the refraction at the upper and lower limbs, its effect upon distance of centres will be eliminated.

If $d\mathrm{R}$, dr be the corrections required to the Tabular Semidiameters R, r of the Sun and *Venus* respectively; Δ the Local Tabular distance of centres; and if the True Mean Solar Parallax = Tabular M. S. Parallax $\left(1+\frac{n}{100}\right)$, we have for each photograph, neglecting errors of longitude,

$$\text{True distance of centres} = \mathrm{M} + \frac{\mathrm{M}}{\mathrm{R}+r}(d\mathrm{R}+dr) = \Delta + \mathrm{A}.n + \mathrm{B}.d\mathrm{RA} + \mathrm{C}.d\mathrm{NPD}.$$

The coefficients A, B, C, D have been computed for each photograph by the formulæ given in the *Monthly Notices*, vol. xxxv., p. 277. The equations thus obtained were formed into groups of about 10, and the means taken as below:—

* And only with sensibly circular images such as those obtained with a high Sun.

(1) From Mr. Burton's measures—

			No. of Photos.
Thebes	6·06	$= -\cdot1413\,n - \cdot0422\,d\mathrm{RA} - \cdot9985\,d\mathrm{NPD} - \cdot8571\,(d\mathrm{R}+dr)$	11
	5·82	$= -\cdot1629\,n - \cdot1188\,d\mathrm{RA} - \cdot9914\,d\mathrm{NPD} - \cdot8818\,(d\mathrm{R}+dr)$	11
	6·40	$= -\cdot1773\,n - \cdot1782\,d\mathrm{RA} - \cdot9810\,d\mathrm{NPD} - \cdot9071\,(d\mathrm{R}+dr)$	11
Honolulu	8·99	$= -\cdot2280\,n + \cdot6286\,d\mathrm{RA} - \cdot7318\,d\mathrm{NPD} - \cdot9200\,(d\mathrm{R}+dr)$	11
	8·86	$= -\cdot2263\,n + \cdot5998\,d\mathrm{RA} - \cdot7596\,d\mathrm{NPD} - \cdot9009\,(d\mathrm{R}+dr)$	11
	8·30	$= -\cdot2181\,n + \cdot5342\,d\mathrm{RA} - \cdot8139\,d\mathrm{NPD} - \cdot8681\,(d\mathrm{R}+dr)$	10
Rodriguez	5·58	$= +\cdot1725\,n + \cdot5500\,d\mathrm{RA} - \cdot8025\,d\mathrm{NPD} - \cdot9003\,(d\mathrm{R}+dr)$	11
	6·85	$= +\cdot1423\,n + \cdot4640\,d\mathrm{RA} - \cdot8633\,d\mathrm{NPD} - \cdot8682\,(d\mathrm{R}+dr)$	10
	4·90	$= +\cdot0902\,n + \cdot3032\,d\mathrm{RA} - \cdot9380\,d\mathrm{NPD} - \cdot8398\,(d\mathrm{R}+dr)$	10
	5·13	$= +\cdot0053\,n - \cdot0119\,d\mathrm{RA} - \cdot9985\,d\mathrm{NPD} - \cdot8610\,(d\mathrm{R}+dr)$	11
	3·34	$= -\cdot0140\,n - \cdot1139\,d\mathrm{RA} - \cdot9920\,d\mathrm{NPD} - \cdot8899\,(d\mathrm{R}+dr)$	11
Burnham	6·70	$= +\cdot0300\,n + \cdot4803\,d\mathrm{RA} - \cdot8508\,d\mathrm{NPD} - \cdot8729\,(d\mathrm{R}+dr)$	13
Kerguelen	5·34	$= +\cdot1669\,n + \cdot3042\,d\mathrm{RA} - \cdot9438\,d\mathrm{NPD} - \cdot8440\,(d\mathrm{R}+dr)$	8

From these, considered as of equal weight, we have the three normal equations,

$$-5''\cdot352 = +\cdot3159\,n - \cdot0836\,d\mathrm{RA} + \cdot4726\,d\mathrm{NPD} + \cdot5147\,(d\mathrm{R}+dr)$$
$$+25\cdot446 = -\cdot0836\,n + 2\cdot0340\,d\mathrm{RA} - 2\cdot7129\,d\mathrm{NPD} - 2\cdot9968\,(d\mathrm{R}+dr)$$
$$-72\cdot327 = +\cdot4726\,n - 2\cdot7129\,d\mathrm{RA} + 10\cdot5821\,d\mathrm{NPD} + 10\cdot2255\,(d\mathrm{R}+dr);$$

and their solution is

$$n = -7\cdot88 - \cdot233\,(d\mathrm{R}+dr),$$
$$d\mathrm{RA} = +5''\cdot38 + \cdot287\,(d\mathrm{R}+dr),$$
$$d\mathrm{NPD} = -5\cdot10 - \cdot882\,(d\mathrm{R}+dr);$$

whence the mean Solar Parallax $= 8''\cdot25 - \cdot021\,(d\mathrm{R}+dr)$.

(2) From my own measures—

			No. of Photos.
Thebes	5·02	$= -\cdot1567\,n - \cdot0966\,d\mathrm{RA} - \cdot9930\,d\mathrm{NPD} - \cdot8753\,(d\mathrm{R}+dr)$	12
	5·85	$= -\cdot1773\,n - \cdot1782\,d\mathrm{RA} - \cdot9810\,d\mathrm{NPD} - \cdot9071\,(d\mathrm{R}+dr)$	11
Honolulu	8·00	$= -\cdot2280\,n + \cdot6275\,d\mathrm{RA} - \cdot7329\,d\mathrm{NPD} - \cdot9182\,(d\mathrm{R}+dr)$	12
	8·26	$= -\cdot2259\,n + \cdot5949\,d\mathrm{RA} - \cdot7641\,d\mathrm{NPD} - \cdot8974\,(d\mathrm{R}+dr)$	12
Rodriguez	5·08	$= +\cdot1738\,n + \cdot5537\,d\mathrm{RA} - \cdot7996\,d\mathrm{NPD} - \cdot9016\,(d\mathrm{R}+dr)$	9
	4·99	$= +\cdot1444\,n + \cdot4704\,d\mathrm{RA} - \cdot8595\,d\mathrm{NPD} - \cdot8680\,(d\mathrm{R}+dr)$	6
	4·56	$= +\cdot1058\,n + \cdot3556\,d\mathrm{RA} - \cdot9223\,d\mathrm{NPD} - \cdot8407\,(d\mathrm{R}+dr)$	8
	4·21	$= +\cdot0036\,n - \cdot0197\,d\mathrm{RA} - \cdot9986\,d\mathrm{NPD} - \cdot8620\,(d\mathrm{R}+dr)$	10
	2·59	$= -\cdot0141\,n - \cdot1142\,d\mathrm{RA} - \cdot9921\,d\mathrm{NPD} - \cdot8890\,(d\mathrm{R}+dr)$	9
Burnham	5·77	$= +\cdot0179\,n + \cdot5699\,d\mathrm{RA} - \cdot7862\,d\mathrm{NPD} - \cdot9072\,(d\mathrm{R}+dr)$	3
	6·05	$= +\cdot0336\,n + \cdot4494\,d\mathrm{RA} - \cdot8702\,d\mathrm{NPD} - \cdot8619\,(d\mathrm{R}+dr)$	10

From these, weighted as the square root of the number of photographs, are obtained the normal equations,

$$
\begin{aligned}
-\ 46{\cdot}84 &= +2{\cdot}377\ n - 1{\cdot}029\ d\mathrm{RA} + 4{\cdot}388\ d\mathrm{NPD} + 5{\cdot}231\ (d\mathrm{R}+dr)\\
+\ 188{\cdot}09 &= -1{\cdot}029\ n + 17{\cdot}680\ d\mathrm{RA} - 21{\cdot}002\ d\mathrm{NPD} - 24{\cdot}232\ (d\mathrm{R}+dr)\\
-\ 496{\cdot}40 &= +4{\cdot}838\ n - 21{\cdot}002\ d\mathrm{RA} + 81{\cdot}112\ d\mathrm{NPD} + 79{\cdot}868\ (d\mathrm{R}+dr);
\end{aligned}
$$

and their solution is

$$
\begin{aligned}
n &= -9{\cdot}70 - {\cdot}445\ (d\mathrm{R}+dr),\\
d\mathrm{RA} &= +5{\cdot}04 + {\cdot}298\ (d\mathrm{R}+dr);\\
d\mathrm{NPD} &= -3{\cdot}36 - {\cdot}881\ (d\mathrm{R}+dr);
\end{aligned}
$$

whence the Mean Solar Parallax $= 8''{\cdot}08 - {\cdot}040\ (d\mathrm{R}+dr)$.

These values of the parallax being quite inadmissible, the Astronomer Royal suggested that the tolerably well-known values of n, dRA, and dNPD, obtained from the contact observations, should be substituted in the equations, so that the outstanding quantities might appear as errors of the distance of centres or of the photographic semidiameters. Accordingly, n being taken $-\ 1{\cdot}117$, corresponding to the mean solar parallax $8''{\cdot}85$, $d\mathrm{RA} = +5''{\cdot}81$, $d\mathrm{NPD} = -5''{\cdot}33$, the following equations result:—

Station.	From Burton's measures.	No. of Photos.	From Tupman's measures.	No. of Photos.
	"		"	
Thebes	·857 $(d\mathrm{R}+dr) = -0{\cdot}83$	11		
	·882 $(d\mathrm{R}+dr) = -1{\cdot}04$	11	·875 $(d\mathrm{R}+dr) = -0{\cdot}11$	12
	·907 $(d\mathrm{R}+dr) = -2{\cdot}01$	11	·907 $(d\mathrm{R}+dr) = -1{\cdot}46$	11
Honolulu	·920 $(d\mathrm{R}+dr) = -1{\cdot}18$	11		
	·901 $(d\mathrm{R}+dr) = -1{\cdot}07$	11	·918 $(d\mathrm{R}+dr) = -0{\cdot}19$	12
	·868 $(d\mathrm{R}+dr) = -0{\cdot}61$	10	·897 $(d\mathrm{R}+dr) = -0{\cdot}48$	12
Rodriguez	·900 $(d\mathrm{R}+dr) = +1{\cdot}07$	11	·902 $(d\mathrm{R}+dr) = +2{\cdot}20$	9
	·868 $(d\mathrm{R}+dr) = +0{\cdot}29$	10	·868 $(d\mathrm{R}+dr) = +2{\cdot}16$	6
	·840 $(d\mathrm{R}+dr) = +1{\cdot}76$	10	·841 $(d\mathrm{R}+dr) = +2{\cdot}30$	8
	·861 $(d\mathrm{R}+dr) = +0{\cdot}12$	11	·862 $(d\mathrm{R}+dr) = +1{\cdot}09$	10
	·890 $(d\mathrm{R}+dr) = +1{\cdot}30$	11	·889 $(d\mathrm{R}+dr) = +2{\cdot}05$	9
Burnham	·873 $(d\mathrm{R}+dr) = +0{\cdot}59$	13	·907 $(d\mathrm{R}+dr) = +1{\cdot}71$	3
			·862 $(d\mathrm{R}+dr) = +1{\cdot}19$	10
Kerguelen	·844 $(d\mathrm{R}+dr) = +1{\cdot}27$	8		0

The discordances here shown are of three kinds:—

1° Taking the Rodriguez results by themselves, as they are the most numerous and the photographs present the sharpest limbs, Mr. Burton's measures show a discordance of $1''{\cdot}6$ between the means of two contiguous groups. My measures also have

the greatest discordance, 1″·2, between the same groups. These discordances are obviously due to the inherent defects of the photographic images, and are of such magnitude as to forbid the employment of the measures in the determination of the solar parallax.

2° There is a curious systematic difference between Mr. Burton and myself amounting to nearly 1″. Mr. Burton invariably placed the negative in the measuring instrument with the planet on the left-hand side of the Sun's centre, whereas I always placed it with the planet on the right-hand side. It is difficult to conceive, however, in what manner this can have affected our appreciation of the diameters or of the distance of centres.

3° There is a systematic difference between the Northern and the Southern stations of a very puzzling character, affecting the distance of centres to the extent of about 2″, or about one-twelfth part of the total relative parallactic displacement of the planet referred to the centre of the Sun. No cause for this has at present been suggested. These discordances support the decision of the American Commission that the photographic diameter of the Sun cannot be relied on when accuracy is required.

Additions and Corrections to Captain Tupman's Paper in the Monthly Notices for June 1878.

Page 449, line 18. The normal equations are

$$+31{\cdot}0000\,i - 0{\cdot}0787\,n = -8{\cdot}3328,$$
$$-\ 0{\cdot}0787\,i + 0{\cdot}6112\,n = -0{\cdot}5744.$$

Page 450, line 22. The normal equations are

$$+28{\cdot}0000\,i - 0{\cdot}2055\,n = -1{\cdot}7466,$$
$$-\ 0{\cdot}2055\,i + 0{\cdot}6565\,n = -0{\cdot}7581;$$

whence

$$i = -0{\cdot}177, \qquad n = -1{\cdot}071.$$

Page 453, line 2. The normal equations are

$$+55{\cdot}0000\,e + 0{\cdot}9377\,n = -0{\cdot}6794,$$
$$+\ 0{\cdot}9377\,e + 1{\cdot}0793\,n = -1{\cdot}2416.$$

Page 454, line 11. The normal equations are

$$+48{\cdot}0000\,e + 1{\cdot}5013\,n = -3{\cdot}7696,$$
$$+\ 1{\cdot}5013\,e + 0{\cdot}9343\,n = -0{\cdot}6729.$$

Spectroscopic Observations of the Eclipse of the Moon, 1878, August 12, made at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal*).

The following observations were made by Mr. Maunder, with the Great Equatoreal and Single Prism Spectroscope:—

The Moon, as viewed in the finder of the Great Equatoreal, appeared to have the eclipsed part completely cut out from it, the shadow being so dense and black that the outline of the Moon's limb could not be traced under it, even in imagination; nor could any features be made out on the eclipsed part, except at the very edge of the shadow. As viewed in the Single Prism Spectroscope, there was by no means the same difference in the amount of apparent brilliancy. The spectrum of the bright part was about three times as bright as that of the part in shadow, and could not be traced much further either way, the bright part being visible from Fraunhofer's cluster B to midway between *h* and H; the eclipsed part from about wave-length 6450 tenth-metres ±, near Band *β* of the Brewster-Gladstone spectrum, to *h*. The spectrum of the eclipsed part presented a great contrast to its appearance during the total eclipse of 1877, August 23, in the almost total absence of the telluric bands; Band *δ*, which was so dark and broad on that occasion, being now scarcely visible; and the only other one seen was one just suspected near Band *σ*. The only other evidence of atmospheric absorption was a general absorption beyond D to the red, and beyond G to the violet.

Royal Observatory, Greenwich,
1878, *August* 31.

The Proper Motions of certain Stars in the Greenwich Seven-Year Catalogue for 1864. By A. W. Downing, B.A.

Having occasion lately to refer to the proper motions of stars in the first four hours of right ascension, I was surprised to find that there were still so many of the stars observed by Bradley whose proper motions have not been determined by comparison with accurate modern places; so that astronomers still use, in many cases, the untrustworthy proper motions of the British Association Catalogue.

The present paper is an attempt to partially supply, for stars in the first four hours of right ascension, this deficiency in our knowledge of accurate proper motions. It contains the proper motions of the stars, within the above-mentioned limits of right ascension, which are common to Bradley's Catalogue in Bessel's *Fundamenta Astronomiæ* and the Greenwich Seven-Year Catalogue for 1864, the quantities of proper motion being deduced

from a comparison of the places given in these catalogues. I have, of course, omitted the Bradley stars in the latter catalogue whose proper motions have been determined by Main or Stone, and I have also omitted those which appear in the new Nine-Year Catalogue for 1872, so that the places of all in my list must depend, at least for some time to come, on the Seven-Year Catalogue for 1864.

The method of computation which I have adopted is that explained by Mr. Main in the 19th volume of the *Memoirs* of this Society, viz., if p_1, p_2, and p_3 be the annual precessions, in R.A. or N.P.D., for any star at equidistant epochs, the mean annual precession $= \frac{1}{6}(p_1 + 4p_2 + p_3)$; and I have applied the necessary corrections to Bessel's precessions as given in the *Fundamenta* to reduce them to precessions deduced from Peters' Constants. Then, as Bessel has given the precessions of each star for the epochs 1755 and 1800, it is easy from the latter to compute the precession for the middle year between 1755 and the mean year of observation of the star given in the Greenwich Catalogue, and from the precession given in the latter catalogue to compute it for the mean year of observation, and thus obtain three precessions at equidistant epochs, and thence, by means of the formula given above, to find the mean annual precession.

In computing the mean annual motions I have been careful to correct the places in the Seven-Year Catalogue for the quantity of proper motion applied to the observed place to reduce it to the mean epoch of the catalogue, but the places in the *Fundamenta* have been used without any correction whatever. Of course it is very easy to correct the resulting proper motions for any correction that may be applied to the *Fundamenta*, as it is simply $-\frac{\Delta\alpha}{109}$ or $-\frac{\Delta\delta}{109}$, where $\Delta\alpha$ and $\Delta\delta$ are the corrections to the R.A. and N.P.D. respectively.

Having found the mean annual precession and mean annual motion, then in all cases

Proper motion = Mean annual motion − Mean annual precession.

As none of the stars whose proper motions are given in this paper are very near the pole, the same method has been used for all.

Unfortunately there are several instances in which a star has been observed by Bradley in one element only, and some in which the place in the *Fundamenta* depends on a single observation. In this latter case I have always marked the resulting proper motion with an asterisk.

No.	Name of Star.	Approx. R.A. 1864. h	m	Mean Precession in R.A. s	Mean Annual Motion. s	Proper Motion in R.A. s	Mean Precession in N.P.D. "	Mean Annual Motion. "	Proper Motion in N.P.D. "
1	4 Ceti	0	1	+3·0717	+3·0705	−0·001	−20·058	−20·077	−0·02
2	5 Ceti	0	1	3·0715	3·0670	−0·005	20·059	20·058	0·00
3	23 Andromedæ	0	6	3·0894	3·0767	−0·013	20·057	19·919	+0·14
4	7 Ceti	0	8	3·0604	3·0586	−0·002	20·054	19·981	+0·07
5	36 Piscium	0	9	3·0755	3·0716	−0·004	20·050	20·022	+0·03
6	37 Piscium	0	10	3·0804	3·0784	−0·002			
7	38 Piscium, 2nd star	0	10	3·0772	3·0788	+0·002	20·048	20·128	−0·08
8	39 Piscium	0	11	3·0843	3·0998	+0·016	20·047	20·023	+0·02
9	42 Piscium	0	15	3·0873	3·0906	+0·003	20·029	20·037	−0·01
10	9 Ceti	0	16	3·0530	3·0780	+0·025	20·026	20·082	−0·06
11	Bradley 27	0	19	3·1038	3·1016	−0·002*			
12	Bradley 30	0	20	3·0986	3·1053	+0·007*	20·000	20·008	−0·01*
13	46 Piscium	0	21	3·1063	3·1025	−0·004	19·997	19·983	+0·01
14	47 Piscium	0	21	3·1032	3·1110	+0·008	19·996	20·027	−0·03
15	48 Piscium	0	21	3·1005	3·1000	−0·001	19·995	19·982	+0·01
16	49 Piscium	0	24	3·1038	3·0978	−0·006	19·975	19·996	−0·02
17	Bradley 41	0	25	3·1049	3·1026	−0·002	19·970	19·943	+0·03
18	54 Piscium	0	32	3·1344	3·0991	−0·035	19·892	19·518	+0·37
19	55 Piscium	0	33	3·1360	3·1365	+0·001	19·888	19·850	+0·04
20	32 Andromedæ	0	34	3·2138	3·2138	0·000	19·877	19·876	0·00

21	Bradley 64	0 35	3·2242	3·2209	−0·003*			
22	Bradley 68	0 37	3·2818	3·2761	−0·006			
23	18 Ceti	0 39	3·0194	3·0130	−0·006	19·813	19·593	+0·22
24	57 Piscium	0 39	3·1260	3·1234	−0·003	19·802	19·753	+0·05
25	61 Piscium	0 41	3·1507	3·1589	+0·008	19·785	19·771	+0·01
26	62 Piscium	0 41	3·0955	3·0987	+0·003	19·776	19·765	+0·01
27	64 Piscium	0 42	3·1357	3·1324	−0·003	19·768	19·554	+0·21
28	*i* Piscium	0 43	3·1870	3·1913	+0·004	19·756	19·736	+0·02
29	ϕ^2 Ceti	0 43	3·0225	3·0046	−0·018	19·744	19·504	+0·24
30	66 Piscium	0 47	3·1660	3·1541	−0·002	19·681	19·675	+0·01
31	21 Ceti	0 47	3·0264	3·0262	0·000	19·678	19·618	+0·06
32	ϕ^3 Ceti	0 49	3·0123	3·0086	−0·003	19·646	19·629	+0·02
33	ϕ^4 Ceti	0 52	3·0084	3·0036	−0·005	19·597	19·562	+0·04
34	25 Ceti	0 56	3·0394	3·0287	−0·011	19·515	19·410	+0·11
35	Bradley 112	0 56	3·4823	3·4648	−0·018*			
36	Bradley 114	0 57	3·7376	3·7397	+0·002*			
37	ψ^1 Piscium	0 58	3·1907	3·1938	+0·003	19·473	19·426	+0·05
38	Bradley 122	0 58	3·1907	3·1928	+0·002	19·473	19·426	+0·05
39	27 Ceti	0 59	3·0081	3·0038	−0·004	19·460	19·424	+0·04
40	28 Ceti	0 59	3·0083	3·0077	−0·001	19·450	19·470	−0·02
41	78 Piscium	1 1	3·2710	3·2836	+0·013	19·429	19·381	+0·05
42	ψ^2 Piscium	1 1	+3·1908	+3·1947	+0·004	−19·423	−19·327	+0·10

No.	Name of Star.	Approx. R.A. 1864. h	m	Mean Precession in R.A. s	Mean Annual Motion. s	Proper Motion in R.A. s	Mean Precession in N.P.D. ″	Mean Annual Motion. ″	Proper Motion in N.P.D. ″
43	30 Ceti	1	1	+3·0071	+3·0159	+0·009	−19·414	−19·409	+0·01
44	29 Ceti	1	1	3·0770	3·0833	+0·006	19·416	18·952	+0·46
45	44 Andromedæ	1	3	3·3709	3·3578	−0·013	19·383	19·320	+0·06
46	32 Cassiopeiæ	1	3	3·7761	3·7743	−0·002	19·385	19·371	+0·01
47	32 Ceti	1	3	3·0099	3·0062	−0·004	19·359	19·299	+0·06
48	45 Andromedæ	1	4	3·3317	3·3287	−0·003	19·361	19·365	0·00*
49	*g* Piscium	1	4	3·2768	3·2748	−0·002	19·359	19·349	+0·01*
50	Bradley 153	1	6	3·2715	3·2737	+0·002			
51	35 Ceti	1	6	3·0803	3·0752	−0·005			
52	36 Ceti	1	6	3·0212	3·0187	−0·003	19·298	19·277	+0·02
53	ϕ Piscium	1	6	3·2309	3·2297	−0·001	19·292	19·259	+0·03
54	87 Piscium	1	7	3·1709	3·1656	−0·005	19·279	19·251	+0·03
55	88 Piscium	1	8	3·1103	3·1071	−0·003	19·260	19·225	+0·04
56	39 Ceti	1	10	3·0475	3·0386	−0·009	19·208	19·138	+0·07
57	41 Ceti	1	11	3·0113	3·0101	−0·001	19·176	19·117	+0·06
58	Bradley 166	1	12	4·8594	4·8585	−0·001			
59	35 Cassiopeiæ, 2nd star	1	12	3·8687	3·8758	+0·007	19·166	19·130	+0·04*
60	*l* Piscium	1	14	3·2847	3·2858	+0·001	19·111	19·020	+0·09
61	43 Ceti	1	16	3·0605	3·0578	−0·003	19·052	19·038	+0·01
62	47 Andromedæ	1	16	3·3833	3·3887	+0·005	19·052	19·030	+0·02

63	92 Piscium	1	17	3·1989	3·2009	+0·002	19·030	18·968	+0·06
64	46 Ceti	1	19	2·9492	2·9489	0·000	18·956	18·957	0·00
65	Bradley 191	1	19	3·0603	3·0599	0·000*			
66	47 Ceti	1	20	2·9601	2·9594	−0·001	18·923	18·909	+0·01
67	95 Piscium	1	21	3·1050	3·1004	−0·005	18·914	18·762	+0·15
68	97 Piscium	1	23	3·2136	3·2152	+0·002			
69	48 Ceti	1	23	2·8794	2·8809	+0·002			
70	Bradley 204	1	25	3·2048	3·2107	+0·006*			
71	Bradley 195	1	26	5·8213	5·8126	−0·009*			
72	100 Piscium	1	28	3·1702	3·1670	−0·003	18·702	18·687	+0·02
73	49 Ceti	1	28	2·9256	2·9282	+0·003	18·684	18·672	+0·01
74	50 Ceti	1	29	2·9259	2·9254	−0·001	18·640	18·641	0·00
75	χ Andromedæ	1	31	3·5453	3·5418	−0·004*	18·597	18·591	+0·01
76	42 Cassiopeiæ	1	32	4·4304	4·4382	+0·008	18·580	18·574	+0·01
77	Bradley 225	1	34	3·3588	3·3565	−0·002	18·499	18·470	+0·03
78	Bradley 236	1	41	3·2309	3·2261	−0·005			
79	Bradley 240	1	44	3·7635	3·7610	−0·003*			
80	55 Andromedæ	1	45	3·5506	3·5471	−0·004	18·104	18·087	+0·02
81	7 Arietis	1	48	3·3183	3·3161	−0·002	17·979	17·970	+0·01
82	47 Cassiopeiæ	1	52	5·5428	5·5676	+0·025*	17·928	17·874	+0·05
83	49 Cassiopeiæ	1	53	5·3672	5·3545	−0·013*	17·874	17·887	−0·01
84	52 Cassiopeiæ	1	53	+4·3253	+4·3230	−0·002	−17·833	−17·815	+0·02

No.	Name of Star.	Approx. R.A. 1864. h	m	Mean Precession in R.A. s	Mean Annual Motion. s	Proper Motion in R.A. s	Mean Precession in N.P.D. "	Mean Annual Motion. "	Proper Motion in N.P.D. "
85	57 Ceti	1	53	+2·8229	+2·8212	−0·002	−17·759	−17·749	+0·01
86	51 Cassiopeiæ	1	54	5·1640	5·1490	−0·015*	17·825	17·793	+0·03*
87	10 Arietis	1	56	3·3662	3·3757	+0·010	17·673	17·679	−0·01
88	60 Ceti	1	56	3·0622	3·0657	+0·004	17·650	17·662	−0·01
89	Bradley 279	1	57	3·3679	3·3675	0·000*			
90	61 Ceti	1	57	3·0570	3·0598	+0·003	17·624	17·545	+0·08
91	Bradley 284	1	59	3·3724	3·3714	−0·001*			
92	11 Arietis	1	59	3·3710	3·3674	−0·004	17·537	17·506	+0·03
93	58 Andromedæ	2	0	3·5633	3·5734	+0·010	17·495	17·435	+0·06
94	14 Arietis	2	2	3·3801	3·3839	+0·004	17·429	17·383	+0·05
95	62 Ceti	2	2	3·0334	3·0272	−0·006	17·391	17·362	+0·03
96	59 Andromedæ	2	3	3·5937	3·5909	−0·003	17·397	17·370	+0·03
97	Bradley 294	2	3	3·5937	3·5910	−0·003			
98	5 Trianguli	2	3	3·4681	3·4700	+0·002*	17·354	17·330	+0·02*
99	*b* Andromedæ	2	5	3·7090	3·7023	−0·007	17·309	17·281	+0·03
100	63 Ceti	2	5	3·0388	3·0384	0·000*	17·285	17·230	+0·06
101	66 Ceti	2	6	3·0318	3·0598	+0·028	17·231	17·165	+0·07
102	Bradley 309	2	6	3·3035	3·3035	0·000			
103	20 Arietis	2	8	3·3929	3·4043	+0·011	17·152	17·076	+0·08
104	21 Arietis	2	8	3·3820	3·3748	−0·007	17·151	17·058	+0·09

105	8 Persei	2	8	4·1383	4·1388	+0·001*	17·158	17·148	+0·01
106	γ Trianguli	2	9	3·5246	3·5282	+0·004	17·097	17·057	+0·04
107	23 Arietis	2	12	3·3135	3·3106	−0·003	16·982	16·859	+0·12
108	Bradley 325	2	12	3·8186	3·8195	+0·001	16·985	16·978	+0·01
109	63 Andromedæ	2	12	3·8975	3·8966	−0·001	16·985	16·952	+0·03
110	70 Ceti	2	15	3·0487	3·0454	−0·003	16·796	16·727	+0·07
111	64 Andromedæ	2	15	3·9129	3·9127	0·000	16·824	16·779	+0·05
112	10 Persei	2	16	4·1409	4·1388	−0·002	16·820	16·828	−0·01
113	Bradley 336	2	17	3·1934	3·1890	−0·004*			
114	71 Ceti	2	18	3·0236	3·0238	0·000	16·657	16·673	−0·02
115	66 Andromedæ	2	19	3·9492	3·9500	+0·001	16·665	16·557	+0·11
116	ρ Ceti	2	19	2·8954	2·8930	−0·002	16·589	16·572	+0·02
117	11 Trianguli	2	19	3·5203	3·5177	−0·003	16·614	16·582	+0·03
118	25 Arietis	2	20	3·1952	3·1746	−0·021	16·564	16·344	+0·22
119	13 Trianguli	2	21	3·4915	3·4846	−0·007	16·543	16·595	−0·05
120	26 Arietis	2	23	3·3353	3·3379	+0·003	16·431	16·396	+0·04
121	σ Ceti	2	26	3·8457	3·8395	−0·006	16·273	16·175	+0·10
122	Bradley 355	2	26	3·3255	3·3292	+0·004	16·277	16·292	−0·02*
123	77 Ceti	2	28	2·9498	2·9527	+0·003	16·157	16·066	+0·09
124	80 Ceti	2	29	2·9493	2·9408	−0·009	16·089	16·019	+0·07
125	Bradley 358	2	31	+4·9705	+4·9980	+0·028*	−16·109	−16·089	+0·02

No.	Name of Star.	Approx. R.A. 1864. h m	Mean Precession in RA. s	Mean Annual Motion. s	Proper Motion in R.A. s	Mean Precession in N.P.D. "	Mean Annual Motion. "	Proper Motion in N.P.D. "
126	81 Ceti	2 31	+3·0116	+3·0140	+0·002	−16·010	−15·971	+0·04
127	11 Persei	2 33	4·2012	4·2061	+0·005	15·932	15·913	+0·02
128	84 Ceti	2 34	3·0495	3·0533	+0·004*	15·833	15·700	+0·13
129	Bradley 379	2 35	3·2121	3·2106	−0·002*			
130	Bradley 391	2 41	3·4562	3·4600	+0·004	15·490	15·480	+0·01
131	Bradley 403	2 45	3·1578	3·1589	+0·001*			
132	ρ^1 Arietis	2 47	3·3390	3·3402	+0·001	15·122	15·100	+0·02
133	Bradley 396	2 51	8·4248	8·3936	−0·031*	15·171	15·173	0·00
134	Bradley 416	2 53	3·7105	3·7141	+0·004*	14·820	14·780	+0·04*
135	50 Arietis	2 53	3·3513	3·3479	−0·003			
136	7 Eridani	2 54	3·0133	3·0116	−0·002*	14·711	14·732	−0·02
137	ρ^1 Eridani	2 54	2·9362	2·9411	+0·005	14·677	14·588	+0·09
138	93 Ceti	2 55	3·1286	3·1233	−0·005	14·642	14·639	0·00
139	ρ^2 Eridani	2 56	2·9345	2·9342	0·000	14·586	14·571	+0·02
140	52 Arietis	2 57	3·4914	3·4884	−0·003	14·530	14·506	+0·02
141	54 Arietis	3 1	3·3761	3·3756	−0·001	14·331	14·346	−0·02
142	Bradley 444	3 2	3·5340	3·5335	−0·001*			

No. 142. The R.A. of the *Fundamenta* has been increased 1′.

143	59 Arietis	3	12	3·5573	3·5538	−0·004	13·639	13·549	+0·09
144	κ^1 Ceti	3	12	3·1169	3·1331	+0·016	13·587	13·605	−0·02
145	*l* Persei	3	12	3·9745	3·9676	−0·007	13·626	13·607	+0·02
146	60 Arietis	3	12	3·5288	3·5288	0·000	13·600	13·496	+0·10
147	62 Arietis	3	14	3·5734	3·5738	0·000	13·497	13·457	+0·04
148	Bradley 475	3	17	3·4619	3·4663	+0·004*			
149	Bradley 480	3	21	4·1757	4·1800	+0·004	13·072	13·021	+0·05
150	Bradley 483	3	23	4·1790	4·1787	0·000			
151	36 Persei	3	23	4·1077	4·1030	−0·005	12·932	12·849	+0·08
152	Bradley 490	3	27	3·7030	3·7047	+0·002			
153	Bradley 492	3	27	3·6963	3·6921	−0·004			
154	Bradley 496	3	30	3·0704	3·0739	+0·004	12·413	12·232	+0·18
155	21 Eridani	3	32	2·9551	2·9500	−0·005	12·234	12·004	+0·23
156	*o* Persei	3	34	3·7703	3·7700	0·000	12·181	12·164	+0·02
157	22 Eridani	3	34	2·9623	2·9601	−0·002	12·124	12·115	+0·01
158	24 Eridani	3	37	3·0377	3·0343	−0·003	11·867	11·853	+0·01
159	21 Tauri	3	38	3·5492	3·5509	+0·002	11·892	11·839	+0·05
160	22 Tauri	3	38	3·5490	3·5490	0·000	11·882	11·820	+0·06*
161	w^1 Tauri	3	38	3·1741	3·1744	0·000*	11·816	11·788	+0·03
162	π Eridani	3	40	2·8262	2·8256	−0·001*	11·705	11·752	−0·05
163	Bradley 522	3	40	+3·5281	+3·5272	−0·001	−11·709	−11·648	+0·06

No.	Name of Star.	Approx. R.A. 1864. h m	Mean Precession in R.A. s	Mean Annual Motion. s	Proper Motion in R.A. s	Mean Precession in N.P.D. "	Mean Annual Motion. "	Proper Motion in N.P.D. "
164	Bradley 523	3 40	+3·5491	+3·5496	+0·001*			
165	26 Tauri	3 41	3·5388	3·5379	−0·001			
166	ν Persei	3 41	3·7639	3·7604	−0·004	−11·669	−11·670	0·00
167	ν^2 Tauri	3 45	3·1859	3·1833	−0·003	11·369	11·346	+0·02
168	29 Eridani	3 46	2·9620	2·9597	−0·002			
169	30 Eridani	3 46	2·9560	2·9544	−0·002	11·264	11·241	+0·02
170	A Persei	3 47	4·3932	4·4011	+0·008	11·316	11·177	+0·14
171	τ^8 Eridani	3 48	2·5472	2·5490	+0·002	11·096	11·076	+0·02
172	Bradley 545	3 53	3·5414	3·5417	0·000	10·798	10·744	+0·05
173	τ^9 Eridani	3 54	2·5529	2·5528	0·000	10·641	10·646	−0·01
174	40 Tauri	3 57	3·1687	3·1658	−0·003	10·504	10·476	+0·03
175	49 Persei	3 59	3·9412	3·9321	−0·009	10·348	10·186	+0·16
176	50 Persei	3 59	+3·9515	+3·9660	+0·014	−10·328	−10·129	+0·20

Letter from Professor Watson to Mr. Hind, Superintendent of the "Nautical Almanac."

I doubt not that you will be interested to receive more precise information about the observations which I made on July 29 than has yet been published.

Upon my return from the Eclipse Expedition, in order to be able to answer numerous inquiries which were addressed to me, I made an approximate reading of the circles upon which I had marked the positions observed, and the resulting places of two new stars which I observed were immediately communicated to several astronomers in this country and in Europe, and also to the *American Journal of Science*. As soon as I had the leisure, I made a more careful determination, and I noticed, upon revolving the alidade of the reading-circle, that the circle to be read had a very considerable excentricity, as it had been hurriedly mounted. Since there would, in any event, be an error of excentricity to be determined in changing the hour-circle from the instrument to the reading-circle, I did not remount it, but determined the necessary corrections by means of the four readings upon the Sun.

I have made ten readings upon each mark, backward and forward, so that each reading is an independent determination. The results derived from the mean of these readings are shown by the following:—

Chronometer Times. By Newcomb's.			By Watson's.			Washington M.T.			Object observed.	Circle Reading.		
h	m	s	h	m	s	h	m	s		°	′	′
			4	39	50	5	7	31	Sun	165	31·6	±0·7
10	29	15				5	16	37	(*a*)	161	1·6	±0·4
10	30	24				5	17	46	(*b*)	156	7·5	±0·5
			4	55	10	5	22	51	Sun	161	38·3	±0·5
			5	4	50	5	32	31	Sun	159	7·0	±0·3
			5	46	55	6	14	36	Sun	148	21·7	±0·7

By comparing the mean of the second and third readings upon the Sun with the extreme readings, I have obtained the following expression for the correction for excentricity:—

$$R_c = R + 103'.7 \sin (R + 63^\circ.2);$$

so that we have

Washington M.T.			Object observed.	Corrected Circle Reading.	
h	m	s		°	′
5	7	31	Sun	164	13·7
5	16	37	(*a*)	159	49·3
5	17	46	(*b*)	155	1·8
5	22	51	Sun	160	25·2
5	32	31	Sun	157	57·2
6	14	36	Sun	147	27·4

From these I derive the following differences of right ascension between (*a*) and (*b*) and the Sun :—

From	(*a*)−⊙ Δα m s	(*b*)−⊙ Δα m s
S_1 =	−8 31·6	−26 32·6
S_2 =	−8 37·6	−26 38·2
S_3 =	−8 25·6	−26 26·6
S_4 =	−8 31·5	−26 32·4

The differences of declination previously determined were respectively −0° 22′ and −0° 35′; and hence we have

Washington M.T.		Planet−⊙ Δα m s	Δδ ° ′	Apparent α h m s	δ ° ′
1878 July 29 5 16 37	(*a*)	− 8 32	−0 22	8 27 24	+18 16
29 5 17 46	(*b*)	−26 32	−0 35	8 9 24	+18 3

The magnitude of (*a*) was 4 to 4½; that of (*b*) about 3½. They were probably really brighter because the illumination of the sky was not considered in the estimates.

Before I came to reduce the observations I thought that the star (*b*) might possibly have been *ζ Cancri*, because I did not see the latter also. The sweep was not extended beyond (*b*), and just as I had recorded its place, the Sun came out. The time available for the observations was so short that it was not possible to get more data than I have given above. I did see *θ Cancri* as well as (*a*), and the place of the latter is sure. I consider that of (*b*) to be also sure, and hence that it is a new star.

Ann Arbor, 1878, *Sept.* 3.

Note on Brightness.

By R. A. Proctor, Esq., Hon. Fellow, King's College, London.

I regret that I should have again misunderstood Mr. Stone. I thought he referred only to the light-gathering power of the 26-inch telescope: for he gave no reasons, and I should have expected reasons, for a proposition certainly not self-evident. He asked simply why the satellites of *Mars* can be seen with large telescopes, though invisible with small ones. I think it unlikely that the visibility of the satellites of *Mars* with large telescopes depends at all on the smaller size of the diffraction image. The quantity of light forming the image is the chief point to be considered (I observe that Prof. Newcomb, in estimating the size of

the satellites, considers this point only). I believe it is the only point the eye can appreciate.* In considering the separating powers of telescopes, the size of the diffraction image is of course an all-important point; but it can scarcely affect the space-penetrating power.

1878, *August* 29.

Note upon the Proper Motion of 5 Serpentis.

By Professor T. H. Safford.

The right ascension of this star as given in Bessel's Bradley is about $20'' = 1^s.33$ too large. By a new reduction of Bradley's three observations, I find for 1755·0, but without proper motion, using Newcomb's standard right ascensions,

			Mean R.A. h	m	s
1751	Jan. 7	Old Style	15	6	49·56
	May 26	,,			49·46
	June 3	,,			49·94
Mean (1751·3)			15	6	49·65
The *Fundamenta* gives			15	6	50·90

D'Agelet's one observation as reduced by Dr. Gould,

	h	m	s
1800·0 (1784·4)	15	9	5·7,

needs a correction of $+0^s.74$. The time-stars for this date, June 5, 1784, are *Capella* and *Rigel*, and passed but a few minutes after the Sun. Nineteen small stars observed in the evening give corrections, when compared with their places from Bradley, brought up with Mädler's proper motion, of which one only is negative, and the mean of all is $+0^s.737 \pm 0^s.063$, showing that (probably) the instrument was exposed to the Sun's heat at noon and changed its position during the afternoon.

The correction is confirmed by five other stars, whose right ascensions were found in Bailey's Lalande.

With these corrections, and not without, the right ascensions can be made to agree well with a formula including position for

* In the sense of distinguishing between the intensities of the impressions produced on the optic nerves by two diffraction images, unequal in size but both very small, and equal as regards quantity of light.

1875 and proper motion. As reduced to the equinox and equator of 1875, they are as follows :—

		R.A. h	m	s		C−O s
Bradley	1751·3	15	12	52·95	3 obs.	−0·02
D'Agelet	1784·4			53·62	1 „	+0·14
Lalande	1797·9			54·14	2 „	−0·05
Argelander	1830·			54·90	12 „	+0·10
Robinson	1831·67			54·92	4 „	+0·02
Challis	1836·4			55·07	3 „	−0·01
Airy	1845·			55·38	3 „	−0·11
Wagner	1849·4			55·39	4 „	−0·01
Radcliffe 2	1858·2			55·55	5 „	+0·05
Yarnall	1861·4			55·63	2 „	−0·02
Harvard College	1865·			55·73	8 „	+0·04
The formula compared is		15	12	$56^s{\cdot}022 + 0^s{\cdot}0250\ (t-1875)$.		

I have here omitted the authorities Piazzi, Struve, Taylor, Henderson, and Rümker, which I know only at second hand; they would not alter the result by any large amount. The proper motion as usually given is much less. Argelander has $+0^s{\cdot}0084$, Main $+0^s{\cdot}012$, and Mädler $+0^s{\cdot}0166$; the first two would become nearly correct if the error in Bradley were allowed for. Possibly the error $+0^s{\cdot}0166$ in Argelander's P.M. would account for a portion of the discrepancy in his R.A. I do not know when the observations were made.

There is no trouble with the declination; the annual P.M. is nearly $-0''{\cdot}534$ according to Mädler.

Williams College,
Williamstown, Mass., U.S.A.,
1878, *June* 13.

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